(19) Japan Patent Office (JP)

(12) Official Gazette for Kokai Patent Applications (A)

(11) Japanese Unexamined Patent Application Publication Number: Kokai No. 6-224107

(43) Date of Publication: August 12, 1994 (1994.8.12)

(51) Int.Cl.^{5}

H01L 21/027

G03F 7/20 521 7316-2H

FI

H01L 21/30	311 N	7352-4M
	301 C	7352-4M
	311 S	7352-4M

Request for Examination: Requested

Number of Claims 6 FD (6 pages in total)

---

(21) Application Number: Japanese Patent Application 5-29612

(22) Date of Application: January 27, 1993 (1993.1.27)

(71) Applicant 000004237: NEC Corporation

7-1, Shiba 5-chome, Minato-ku, Tokyo (JP)

(72) Inventor: Tanabe Yasuyoshi, NEC Corporation, 7-1, Shiba 5-chome, Minato-ku, Tokyo (JP)

(74) Agent: Tateno Chieko, Patent Attorney

---

(54) [Title of the Invention] Method and Device for Projection Aligner

(57) [Abstract]

[Purpose] To decrease dimensional variation which occurs due to the effect of standing wave generated when a projection aligning operation is conducted using a single projection

aligner.

[Constitution] Multiple exposure is performed by vertically moving a stage simultaneously when changing the wavelength of a light source, and constantly forming an image on a wafer.

[Scope of Claims for Patent]

[Claim 1] A projection exposure method in which an image of a pattern to be exposed on a glass substrate illuminated by a light emitted from a light source is formed on a wafer coated with a resist using a projection optical system, the method comprising:

a first process where an image of the pattern to be exposed illuminated by a light of a first wavelength emitted from the light source is formed on the wafer; and

a second process where at least one of the glass substrate, the wafer, and the projection optical system is shifted in an optical axis direction, and an image of the pattern to be exposed illuminated by a light of a second wavelength emitted from the light source is formed on the wafer.

[Claim 2] A projection exposure device, the device comprising at least:

a glass substrate having a pattern to be exposed;

a wafer on which a resist is coated;

a light source; and

a projection optical system, wherein the device comprises

a means to change a wavelength of the light source, and

a means to move at least one of the glass substrate, the wafer, and the projection optical system in an optical axis direction.

[Claim 3] A projection exposure method in which an image of a pattern to be exposed on a glass substrate illuminated by a light emitted from a light source is formed on a wafer coated with a resist using a projection optical system, the method comprising:

a first process where an image of the pattern to be exposed illuminated by a light of a first wavelength emitted from the light source is formed on the wafer; and

a second process where a material having a refractive index different from air is inserted between the glass substrate and the wafer, and an image of the pattern to be exposed illuminated by a light of a second wavelength emitted from the light source is formed on the wafer.

[Claim 4] A projection exposure device, the device comprising at least:

a glass substrate having a pattern to be exposed;

a wafer on which a resist is coated;

a light source; and

a projection optical system, wherein the device comprises

a means to change a wavelength of the light source, and

a means to insert a material having a refractive index different from air between the glass substrate and the wafer.

[Claim 5] A projection exposure method in which an image of a pattern to be exposed on a glass substrate illuminated by a light emitted from a light source is formed on a wafer coated with a resist using a projection optical system, the method comprising:

performing one of a single exposure and a multiple exposure with lights of a first wavelength and a second wavelength differing from the first wavelength emitted from the light source, using a multifocal lens as the projection optical system that allow images to be formed at a plurality of positions, wherein

the multifocal lens uses a light of a first wavelength to form an image on the wafer, and also can use a light of a second wavelength to form an image on the wafer.

[Claim 6] A projection exposure device, the device comprising at least:

a glass substrate having a pattern to be exposed;

a wafer on which a resist is coated;

a light source; and

a projection optical system, wherein the device comprises

a means to change a wavelength of the light source to one of a first wavelength and a second wavelength differing from the first wavelength, wherein

the projection optical system is structured of a multifocal lens that allows images to be formed on a wafer using any one of a light of the first wavelength and a light of the second wavelength.

[The Detailed Description of the Invention]

[0001]

[Field of the Invention] The present invention relates to a projection exposure method and a device that can decrease the effect of standing wave generated when a projection exposure to manufacture semiconductors and the like is performed.

[0002]

[Background Art] In fabrication of fine patterns as in semiconductor integrated circuits, projection exposure devices having high productivity are widely used. In the above devices, a dioptric system is used as the projection optical system in some cases, and in such a case, if the wavelength of the light source has a wide bandwidth, this generates chromatic

aberration, which decreases the resolution. Therefore, to obtain high resolution, when a high pressure mercury lamp is used as the light source, light from the light source passes through a filter having an extremely narrow bandwidth, and when a laser is used as the light source, light is narrowbanded using diffraction gratings, prisms, etalons and the like. When such narrowbanded light is used as the light source, the effective amount of light absorbed by a resist varies greatly in accordance with a slight variation in the resist film thickness, due to an influence of standing wave caused by interference between incident light on the resist and reflected light from the resist/wafer interface. This becomes a cause of variation in the resist pattern dimension or of poor resolution. As the projection optical system, when a catadioptric system is used instead of a dioptric system, chromatic aberration can be reduced, and the wavelength of the light source can be broadened. When the wavelength of the light source is broadened, because the standing wave is generated differently when light of has a different wavelength, the effect of standing wave is reduced. Such a catadioptric system is disclosed, for example, in Kokai No. 63-163319 (Japanese Unexamined Patent Application Publication Number 63-163319)(Citation 2). Further, in Kokai No. 63-198324 (Japanese Unexamined Patent Application Publication Number 63-198324)(Citation 1), as a method of decreasing the effect of standing wave, a method in which around an exposure of irradiation amount D_0 using a light of wavelength λ_0 via a glass substrate (mask) having an exposure pattern to be exposed, a light of wavelength λ_1 different from the light of wavelength λ_0 is irradiated by irradiation amount D_1, which

is less than irradiation amount D_0, on the entire surface of the resist or on the area where the pattern is to be formed.
[0003]
[Problems to be Solved by the Invention] However, with the catadioptric system disclosed in Citation 1, alignment of the optical system is difficult, and increasing the numerical aperture is also difficult in design. Further, while the method of Citation 2 can be applied also to the dioptric system, in the case of irradiating the light on the entire surface of the resist, contrast of the image decreases, which leads to poor resolution. Deterioration of contrast can be avoided if the light of wavelength λ_1 is irradiated selectively on the area where the pattern is to be formed, however, Citation 2 does not refer to any specific method of irradiating the light of wavelength λ_1 different from the light of wavelength λ_0 only on the on the area where the pattern is to be formed. If exposure is to be performed two times simply by using two types of exposure devices which are a projection exposure device designed to use the light of wavelength λ_0 and a projection exposure device designed to use the light of wavelength λ_1, production requirements increase, and when a wafer coated with a resist is moved between two different types of projection exposure devices, alignment becomes difficult. The purpose of the present invention is to provide a projection exposure method and a projection exposure device that allows exposure by a plurality of wavelengths to decrease the effect of standing wave to be performed, using a single projection exposure device.
[0004]
[Means for Solving the Problems] A first invention according

to the present invention is a projection exposure method in which an image of a pattern to be exposed on a glass substrate illuminated by a light emitted from a light source is formed on a wafer coated with a resist using a projection optical system, the method comprising: a first process where an image of the pattern to be exposed illuminated by a light of a first wavelength emitted from the light source is formed on the wafer; and a second process where at least one of the glass substrate, the wafer, and the projection optical system is shifted in an optical axis direction, and an image of the pattern to be exposed illuminated by a light of a second wavelength emitted from the light source is formed on the wafer.

[0005] A second invention according to the present invention is a projection exposure device, the device comprising at least: a glass substrate having a pattern to be exposed; a wafer on which a resist is coated; a light source; and a projection optical system, wherein the device comprises a means to change a wavelength of the light source, and a means to move at least one of the glass substrate, the wafer, and the projection optical system in an optical axis direction.

[0006] A third invention according to the present invention is a projection exposure method in which an image of a pattern to be exposed on a glass substrate illuminated by a light emitted from a light source is formed on a wafer coated with a resist using a projection optical system, the method comprising: a first process where an image of the pattern to be exposed illuminated by a light of a first wavelength emitted from the light source is formed on the wafer; and a second process where a material having a refractive index different from air is

inserted between the glass substrate and the wafer, and an image of the pattern to be exposed illuminated by a light of a second wavelength emitted from the light source is formed on the wafer.
[0007] A fourth invention according to the present invention is a projection exposure device, the device comprising at least: a glass substrate having a pattern to be exposed; a wafer on which a resist is coated; a light source; and a projection optical system, wherein the device comprises a means to change a wavelength of the light source, and a means to insert a material having a refractive index different from air between the glass substrate and the wafer.
[0008] A fifth invention according to the present invention is a projection exposure method in which an image of a pattern to be exposed on a glass substrate illuminated by a light emitted from a light source is formed on a wafer coated with a resist using a projection optical system, the method comprising: performing one of a single exposure and a multiple exposure with lights of a first wavelength and a second wavelength differing from the first wavelength emitted from the light source, using a multifocal lens in the projection optical system that allow images to be formed at a plurality of positions, wherein the multifocal lens uses a light of a first wavelength to form an image on the wafer, and also can use a light of a second wavelength to form an image on the wafer.
[0009] A sixth invention according to the present invention is a projection exposure device, the device comprising at least: a glass substrate having a pattern to be exposed; a wafer on which a resist is coated; a light source; and a projection optical system, wherein the device comprises a means to change

a wavelength of the light source to one of a first wavelength and a second wavelength differing from the first wavelength, wherein the projection optical system is structured with a multifocal lens that allows images to be formed on a wafer using any one of a light of the first wavelength and a light of the second wavelength.

[0010]

[Operation] When exposure is performed in a plurality of wavelengths using a single dioptric system to decrease the effect of standing wave, the focal position shifts due to the influence of chromatic aberration. In the first and second inventions, at least one of the mask, the wafer, and the projection optical system is shifted in an optical axis direction to compensate for the shift of the focal position. In the third and fourth inventions, the shift of the focal position is compensated by inserting a material having a refractive index different from air in between the mask and the wafer. In the fifth and sixth inventions, by using a multifocal lens as the projection optical system, an image can be formed on the wafer even if the focal position shifts due to chromatic aberration.

[0011]

[Embodiment] Next, an embodiment of the present invention will be described. FIG. 1 shows an embodiment of a first invention. A KrF excimer laser is used as a light source of a projection exposure device. The KrF excimer laser oscillates at a central wavelength of 248.3 nm with half-value width of 350 pm to emit a pulse light beam, and to restrict the chromatic aberration, the half-value width is narrowed to 3pm. By minutely rotating

a narrowing device, oscillation at a central wavelength of λ_0=248.4nm and at λ_1=248.2nm becomes possible. A focal position variation Δz at this point is given by the following formula.

[0012]

[Formula 1]

$$\Delta z = -(1+m)\frac{f}{n-1}\frac{dn}{d\lambda}\Delta\lambda$$

[0013] In this case, m is the magnification and f is the focal distance of the projection optical system, which are 1/5 and 100mm, respectively. Further, n is the refractive index and $dn/d\lambda$ is the refractive index dispersion at a wavelength λ=248.3nm of a synthetic quartz used for a lens, which are 1.51 and 0.24μm^{-1}, respectively. When the wavelength difference $\Delta\lambda$=-200pm of central wavelengths λ_1 and λ_0 is substituted into the above formula, the focal position variation is 10.5μm. In FIG. 1, the image-forming position of a light 3 of wavelength λ_0 and the image-forming position of a light 4 of wavelength λ_1 are separated by Δz. To compensate this focal position variation, in the embodiment shown in FIG. 1, a wafer 1 on the stage of a projection exposure device is shifted in the direction of the optical axis. Incidentally, a mask or a projection optical system can be shifted instead of the stage. In order to decrease the effect of standing wave most effectively using lights of two wavelengths, when a reflected light from a resist 2 becomes maximum (minimum) due to the variation of resist film thickness on an exposure using the light of wavelength λ_0, then the reflected light from the resist 2 on an exposure using the light of wavelength λ_1 should be made minimum (maximum). A resist film thickness d which satisfies

such a condition is given in the following formula.

[0014]

[Formula 2]

$$d = \left(l + \frac{1}{2}\right) \frac{\lambda^2}{2 n_r \Delta \lambda}$$

[0015] Here, l is zero or a positive integer, and n_r is the refractive index of the resist 2. The thinnest resist film thickness is to be chosen, therefore, l=0, and when substituting n_r=1.6 as the refractive index of the resist, the resist film thickness is 48μm. Because the resist film thickness preferably remaining after developing the resist is around 1μm, the resist has to be separated as a two-layer resist to a lower layer which is a photosensitive agent containing part 5 (1μm) and an upper layer which is a transparent resin part 6 (thickness of 47μm) as shown in FIG. 2.

[0016] Reflectance of the resist surface under the above conditions is shown in FIG. 3. By the slight variation of resist film thickness, while reflectance 7 of the wavelength λ_0 and reflectance 8 of the wavelength λ_1 vary greatly, variation of an average value 9 of the reflectance 7 and the reflectance 8 is extremely small. As described, when using the exposure method of the first invention, the effective amount of light absorbed into the resist becomes almost constant regardless of the film thickness, which allows the effect of standing wave to be decreased greatly.

[0017] FIG. 4 is an embodiment of a projection exposure device of a second invention to realize the exposure method of the first invention. A KrF excimer laser light source 10 is narrowed by a wavelength narrowing device 11 consisting of a diffraction

grating, a prism, an etalon and the like. The central wavelength of the light source 10 is variable by minutely rotating the wavelength narrowing device 11. Because a light reflected by a reflection mirror 12 has a spatially inhomogeneous distribution, the light intensity distribution is homogenized by a homogenizer 13. A light emitted from an illumination optical system 14 becomes a parallel light and irradiates a mask 15, and after being reduced passing through a projection optical system 16, forms an image on a wafer 17 to which a resist is applied. By vertically shifting a stage 18, variation of focal position involved with wavelength variation of the light source 10 can be compensated.

[0018] FIG. 5 shows an embodiment of a third invention. While variation of focal position involved with wavelength variation was compensated by shifting the stage and the like in the first invention, in the third invention, the variation is compensated by inserting a thin film 19 having a refractive index different from air in between the mask and the wafer, and extending the optical path. Because the stage and the like do not have to be shifted, positional deviation that comes with the shift does not occur. Thickness t of the thin film required to extend the optical path length by Δz is given by the following formula.

[0019]

[Formula 3]

$$t = \frac{\Delta z}{n_f - 1}$$

[0020] Here, n_f is the refractive index of the thin film 19. When synthetic quartz is used as the thin film 19, then the film thickness is 20.6μm. As shown in FIG. 5, in the first exposure

using the light 3 of wavelength λ_0, the exposure is performed without the thin film 19 being inserted, and by performing the second exposure with the thin film 19 inserted, the same or similar effect as the first invention can be obtained. Incidentally, as the thin film 19, not only synthetic quartz, but any of an inorganic thin film, an organic thin film, or a gas having a refractive index different from air can be inserted instead.

[0021] FIG. 6 shows an embodiment of a projection exposure device of a fourth invention to realize the exposure method of the third invention. The difference from the projection exposure device of the second invention is that the stage 18 does not have to be shifted between the plurality of exposures, and alternatively, a mechanism of inserting the thin film 19 in between the projection optical system 16 and the wafer 17 has been added. Incidentally, the thin film 19 can be inserted not only between the projection optical system 16 and the wafer 17, and can be placed anywhere as long as the placement is between the mask 15 and the wafer 17.

[0022] FIG. 7 shows an embodiment of a fifth invention. In the fifth invention, a multifocal lens is used in the projection optical system. In the present embodiment, a bifocal lens is used as the multifocal lens, and the distance between two focal points is set to be equal to a focal point moving distance Δz associated with the wavelength variation. With this arrangement, when the first exposure is performed using the light of wavelength λ_0, a light 20 which forms an image on a wafer and a light 21 which forms an image in the air above the wafer are present. When the second exposure is performed,

because the focal position shifts due to the wavelength variation, the light 20 forming an image on the wafer becomes a light 22 of wavelength λ_1 which does not form any images, and the light 21 forming an image in the air above the wafer then becomes a light 23 of wavelength λ_1 which forms an image on the wafer. Incidentally, the exposure does not have to be performed two times, and in the case a laser light source is used that oscillates lights of two wavelengths, the exposure only has to be carried out once. When this exposure method is employed, although the time required for stage movement and the like in the first invention is reduced, contrast of the image deteriorates because the light which does not form any images is present.

[0023] FIG. 8 shows an embodiment of a projection exposure device of a sixth invention to realize the exposure method of the fifth invention. The difference from the projection exposure device of the second invention is that the stage 18 does not have to be shifted between the plurality of exposures, and that the projection optical system 16 has been replaced with a multifocal lens 24.

[0024] Incidentally, in the embodiments related to the first to sixth inventions described so far, a KrF excimer laser is used as a light source, however, an ArF excimer laser, or an i line of a high-pressure mercury vapor lamp or the like may also be used instead. Further, the same or similar effect can also be obtained by performing exposure a plurality of times or in succession, using a plurality of wavelengths or a continuous wavelength serving as the exposure wavelength, besides using only the two wavelengths.

[0025]

[Advantageous Effect of the Invention] As described in detail above, according to the projection exposure method and the projection exposure device of the present invention, exposure by a plurality of wavelengths using a single projection exposure device is possible even when a dioptric system is used as the projection optical system, and as a result, the resist remaining undeveloped and dimensional variation of the resist pattern due to the effect of standing wave can be significantly reduced.

[Brief Description of Drawings]

[FIG. 1] A view used to describe a first invention.

[FIG. 2] A sectional view of a wafer coated with a resist used in the first invention.

[FIG. 3] A view showing a reflectance from a resist and its average value when lights of wavelengths λ_0 and λ_1 are irradiated on a wafer coated with the resist.

[FIG. 4] A view showing a configuration of a projection exposure device according to a second invention.

[FIG. 5] A view used to describe a third invention.

[FIG. 6] A view showing a configuration of a projection exposure device according to a fourth invention.

[FIG. 7] A view used to describe a fifth invention.

[FIG. 8] A view showing a configuration of a projection exposure device according to a sixth invention.

[Description of the Numerals]

1 wafer

2 resist

3 light of wavelength λ_0

4 light of wavelength λ_1

5 photosensitive agent containing part

6 transparent resin part

7 reflectance of wavelength λ_0

8 reflectance of wavelength λ_1

9 average value

10 KrF excimer laser light source

11 wavelength narrowing device

12 reflection mirror

13 homogenizer

14 illumination optical system

15 mask

16 projection optical system

17 wafer

18 stage

19 thin film

24 multifocal lens

DRAWINGS

[FIG. 1]

(a) FIRST EXPOSURE

(b) SECOND EXPOSURE

1 WAFER

2 RESIST

3 LIGHT OF WAVELENGTH λ_0

4 LIGHT OF WAVELENGTH λ_1

[FIG. 2]

1 WAFER

5 PHOTOSENSITIVE AGENT CONTAINING PART

6 TRANSPARENT RESIN PART

[FIG. 3]

REFLECTANCE

RESIST FILM THICKNESS (μm)

[FIG. 4]

10 KrF EXCIMER LASER LIGHT SOURCE

11 WAVELENGTH NARROWING DEVICE

12 REFLECTION MIRROR

13 HOMOGENIZER

14 ILLUMINATION OPTICAL SYSTEM

15 MASK

16 PROJECTION OPTICAL SYSTEM

17 WAFER

18 STAGE

[FIG. 5]

[FIG. 6]

10 KrF EXCIMER LASER LIGHT SOURCE

11 WAVELENGTH NARROWING DEVICE

12 REFLECTION MIRROR

13 HOMOGENIZER

14 ILLUMINATION OPTICAL SYSTEM

15 MASK

16 PROJECTION OPTICAL SYSTEM

17 WAFER

18 STAGE

19 THIN FILM

[FIG. 17]

(a) FIRST EXPOSURE

(b) SECOND EXPOSURE

[FIG. 8]

10 KrF EXCIMER LASER LIGHT SOURCE

11 WAVELENGTH NARROWING DEVICE

12 REFLECTION MIRROR

13 HOMOGENIZER

14 ILLUMINATION OPTICAL SYSTEM

15 MASK

16 PROJECTION OPTICAL SYSTEM

17 WAFER

18 STAGE

24 MULTIFOCAL LENS